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The potential for renovated wastewater use by Massachusetts industries.

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THE POTENTIAL FOR RENOVATED WASTEWATER USE BY MASSACHUSETTS INDUSTRIES

A Thesis Presented

By

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To Betty Olson ...

who planted the seeds to watch them grow

and to Salvatore...

who has and will nourish them.

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ABSTRACT

A study was initiated to assess the acceptance and capability of renovated wastewater supplying water to certain Massachusetts industries. The investigation was to determine if wastewater reuse by industry was a suitable water conservation measure in terms of social, economic, institutional and technological feasibility. Personal interviews, guided by a questionnaire,were held with industrial and public sector individuals. The results indicated that industry is more accepting of wastewater reuse than water resource officials if a project is cost-effective. Although there are few suitable industrial recipients of reclaimed water in Massachusetts, the concept is worthy of more attention as water costs increase, sewage treatment plants are upgraded and alternative water supplies are sought.

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CHAPTER I

INTRODUCTION

It is timely to consider seriously the utilization of reclaimed wastewater. Accelerating urban population growth, an increased demand for electrical energy, water recreation needs, intensive agriculture and a growth trend in manufacturing are some of the major factors creating excessive demands on the total water supply. This unrestrained and steadily increasing need for water raises important questions concerning the soundness of the traditional policy of single use of water prior to discharge. Intentional wastewater renovation and reuse is becoming accepted and is being practiced, albeit with great caution. Nationally it is a topic of intense investigation with indications of becoming a common practice in the future.*

The concept of wastewater reuse is derived from the need to conserve fresh water supplies. Even Massachusetts, situated in the 'water-rich' northeastern U.S., has found it necessary to prioritize water conservation efforts. The Metropolitan District Commission (MDC), which provides cities in the greater Boston area with potable water, has indicated that its Quabbin-Wachusett reservoir system is being overstressed. Cape Cod has discovered that groundwater sources are depleted. Numerous other communities throughout the State find they are water short.

Although there is no reuse activity in the State, its potential has been recognized in the 1978 Massachusetts Water Supply Policy Statement

*In order to differentiate from water recycling, this paper will define reuse as the use, one or more times, of treated municipal sewage effluent. Recycling will be considered as inplant recirculation of water that has been previously used.

which viewed reuse an important component of conservation:

> "Water conservation...has to be enforced as a means to minimize the near-term impact of a water shortage situation. Water conservation, together with selective reuse and secondary use of non-potable supplies phased in at later dates, may also be considered as a potential supplemental water 'source' for meeting a portion of long-term water demands. Water conservation, in addition to being a potential means to reduce consumption, might also be considered as a tool to achieve effective water management and full utilization of present water resources, making additional potable 'supplies' available for other beneficial uses". (Wallace, et al., 1978)

The urgency for water conservation has been acknowledged at the highest federal levels as well. President Carter's water policy statement of June, 1978 emphasized the need for conserving water (Carter, 1978). Soon afterwards, Secretary of the Interior Andrus named Boston as one of five U.S. areas facing drought conditions during the next ten years unless strong conservation measures are immediately taken (Jour. AWWA, 1978). In January, 1979 Andrus referred to the execution of the Administration's water resources policy as the Interior's second priority (after the Alaska national interest land bill) (Env. Rep., 1979). This announcement was prompted by the environmental objectives cited in President Carter's State of the Union Message to Congress in January, 1979. In this speech President Carter said he will propose legislation to increase the role of the states in water policy "through increased water planning grants and through new grants for state water conservation programs" (Carter, 1979). This present study assumes that reuse of municipal effluents should and will be intergrated into comprehensive water conservation plans.

The U.S. is not alone in its concern for water conservation. The renovation of wastewater is alleviating stress on potable sources in a number of cities worldwide. Faced with inadequate supplies, many countries have found that wastewater reuse is a partial solution to their water shortage problems as well as economical. South Africa and Israel, for instance, are world leaders in wastewater reuse research with many years of experience to guide them. In these countries, and others, renovated wastewater is reused not only for industrial purposes, but for agricultural and domestic use. These expanded uses have been investigated intensively and are a part of comprehensive planning efforts.

There are a number of existing features that must be examined to determine the feasibility of a specific wastewater reuse scheme. First, the planning agency must determine if reuse is essential and cost-effective. Next, the most suitable recipients of renovated effluent must be identified. Their attitudes and the attitudes of regional officials whose decisions will impact upon reuse plans must also be assessed. These factors, in particular, need careful analysis long before crisis conditions occur, so that hasty action under pressure does not produce imprudent decisions on careful investment. This study has attempted to elucidate these attitudes in respect to the acceptability and propriety of municipal sewage effluent reuse by industry. The reuse of wastewater by certain industries is a concept that may have potential for reducing the demand on fresh water supplies. It would do so by augmenting these sources with lower quality water where utility for this water may be indicated.

CHAPTER II

LITERATURE REVIEW

Reports on many aspects of wastewater reuse are becoming abundant, although the concept has only gained popularity within the past ten years. The literature pertaining directly to the use of municipal wastewater by industry, and especially to cost-benefit analyses of reuse projects, is more scarce. There is information to be gained from adverse decisions in wastewater reuse planning, but unfortunately, such situations are rarely documented. This section will review discussions that describe examples of industrial use of wastewater and of the related economic and technical factors.

The Bethlehem Steel Company Sparrow Point Plant in Maryland was the first documented example of municipal wastewater reuse by an industry in the United States (Wolman, 1948). Since 1942 a Baltimore sewage treatment plant has supplied an estimated 50 to 120 mgd of low quality effluent that has been successfully used in a once-through cooling system.

Interest in wastewater reuse by industry is not evident in the literature for another fifteen years until Lawrence Cecil (1974) contended that sewage treatment plant effluent can be 'sold' even in areas where water is plentiful and also noted that industrial use of effluent often begins with a critical water shortage, but then is found to be sound business in the never-ending battle to cut costs and increase profits. Further, he stated that if the sewage plant effluent can be treated at a reasonable cost to be non-scaling and non-corrosive, it is marketable. He argued convincingly that wastewater subjected to expensive upgrading is perfectly suitable for reuse and should not be discarded.

The bulk of water used by industry need not be of potable quality. Cooling, the largest single use of industrial water nationwide, consumes billions of gallons a day. Tebbutt (1970) stated that the study of water quality economics can be profitably examined by industry, and that such a study would point out the advantages of sewage effluent as a water source. He listed several water uses in industry as cooling, steam raising, process and potable, with each having a different quality requirement. Depending on the extent of the treatment, wastewater reclamation can potentially provide a source for most of industries' needs.

Kemmer (1970) and Eller et al, (1970) agree with Tebbutt. They stated that the extent of pretreatment will depend on the concentration and type of pollutants typically present in the effluent, and the water quality requirements of the industry. The economics are then based on the cost savings of using a lesser-grade water and on opportunities for multiple reuse of this water within the industry. The problem of ultimate disposal must, of course, be dealt with, realizing that the total mass of solids will not be decreased through conventional reuse practices. The cost of treating the subsequent concentrated water streams must be added to the cost of the inhouse water management.

The use of a dual system of water distribution will be necessary if the alternative water supply is developed. The cost of installing such a system may be substantial. Even so, Haney and Beatty (1977) suggested that dual systems offer a practicable means of conserving a limited supply of superior quality water.

A paper by Garrison and Miele (1977) included industrial reuses (such as for cooling, process water and oilfield repressurization) as potential uses of reclaimed water, but noted that the economics of reuse for industrial purposes becomes unfavorable as the proximity to the reclamation facility decreases. Again,it was mentioned that conveyance and distribution costs must be weighed. The authors stated that the demand for reclaimed water is related directly to the relative cost of imported fresh water supplies and reclaimed water. They also stated that interest in water reuse gives impetus to technology development. As do others, these authors commented on individual industrial requirements and constituents of particular concern. They reported that because cooling systems are subject to scale, corrosion, and biological fouling, phosphates and hardness may have to be controlled and disinfection applied. Beyond this, processing requirements may call for low color and high clarification.

James et al. (1976) discussed requirements for cooling system makeup water. They recognized that proper definition of contaminents is the key factor in determining effluent suitability. They reported that, along with monitoring calcium, orthophosphate, suspended solids and BOD, sulphide levels should not exceed 2 ppm in a cooling tower to avoid destruction of beneficial microorganisms or production of corrosive and offensive hydrogen sulphide.

Potential adverse health effects due to effluent reuse by industry cannot be ignored. One possible hazard exists as a result of biological aerosols generated by cooling towers of electrical power plants. Adams, et al. (1978) have published the only available report on research pertaining to such a potential health risk. Their study evaluated the significance of bacterial aerosol production from cooling towers using wastewater effluent as makeup water including types and numbers of microbial aerosol particles that emanate from cooling towers. Although a hazard to downwind populations may exist if enough opportunistic organisms were aerosolized by cooling towers, it was reported that no significant effect could be predicted. Their conclusion was based on the fact that only low numbers of isolated noninvasive microbe species were found to occur in cooling tower exhaust and that downwind diffusion causes dilution of the bacteria. Added to the dilution effect is the viability decay that occurs in microbial aerosols which is enhanced by ultraviolet light when the plume is formed in the presence of sunlight.

Schmidt, Kugelman and Clements (1975) have produced the most complete report on municipal wastewater reuse in the United States to date. Detailed information was collected from all U.S. industrial reuse operations by means of a questionnaire, correspondence and personal visits. Horsefield and Goff (1976), Smythe (1971), Eller, et al. (1970) and Kemmer (1970) have published similar papers each emphasizing a portion of the industries using municipally treated wastewater.

Schmidt et al. found that there were 358 sites in the U.S. where municipal wastewater reuse was practiced in 1971, with a total annual reclaimed water usage of 133 billion gallons. This study has only recently been updated by a national consulting firm, and the results are as yet, unpublished. The Schmidt study reported that the largest use of reclaimed water is in agriculture. Their sites included only 14 industrial plants; accounting for 40 per cent of the total reuse, or 53.5 billion gallons. Of the latter, three locations were city-owned power plants; private industry represented only eleven plants in the entire nation. The authors noted that there were numerous potential reuse opportunities that remain unrecognized.

TABLE 1: TYPE OF INDUSTRIAL REUSE IN THE UNITED STATES

Type of Reuse	Number of Plants	Percent of Total Water	Reuse Volume (mgd)
Boiler feed	3	17	1
Process	3	17	1
Cooling	12	66	154

TABLE 2: MAJOR INDUSTRY CLASSIFICATIONS USING MUNICIPAL WASTEWATER

Industry	Number of Plants
Power generation	6
Petrochemical	5
Mining and ore processing	2
Basic metal manufacturing	1

Table 1 (from Schmidt et al.) shows that cooling predominates in the reuse of municipal wastewater, accounting for approximately 154 mgd out of a total 156 mgd reused by industry. Table 2, also from the Schmidt et al. paper, points out that power generation plants are the major users of municipal wastewater, followed by petrochemical production.

Schmidt et al. found that the three plants reported using reclaimed water for processing are all in the mining and steelmaking industries. One, the Bethlehem Steel Corporation plant in Baltimore previously mentioned, is responsible for 40 percent of the total industrial reuse volume or 21.4 billion gallons annually.

The economics of industrial reuse are discussed in this paper also, with the estimated costs recorded. These authors concur that economics is the prime motivating force of industry, and the use of reclaimed wastewater is governed by the cost of the alternative water supply procurement and treatment. In locations where public water supplies of good quality and quantity are available at low cost, treatment and reuse of renovated water by industry has not been economically attractive. Thus, it is not surprising that most industrial users of treated municipal effluents are in the semi-arid southwestern states, where water costs are relatively high and water quality lower in terms of TDS and hardness. Schmidt et al. stated that several of the plants did not have an adequate alternative source of water and were dependent on their wastewater effluent supply. However, most of the other plants chose to use reclaimed water because it was more economical that fresh water.

Table 3, also excerpted from Schmidt et al., summarizes the costs to industry using municipal wastewater effluent.

TABLE 3: INDUSTRIAL USERS' COSTS FOR RECLAIMED WATER

	Cost to procure effluent ($/MG)	User treatment cost ($/MG)	Total effluent cost ($/MG)
Bagdad Copper Corp., Bagdad Ariz. (process)	0	0	0
Phelps Dodge Corp., Morenci, Ariz. (process)	0	0	0
City of Burbank, Calif. (cooling)	43	100	143
City of Colorado Springs (cooling)	320	-	-
Bethlehem Steel Corp., Baltimore, MD. (cooling)	1.33	NA	NA
Dow Chemical Co., Midland, Mich. (cooling)	3.33	NA	NA
Nevada Power Co., Las Vegas (cooling)	25	193	225
Champlin Refinery Enid, Okla. (cooling)	7	NA	NA
Southwestern Public Service Co. Amarillo, Tex. (cooling)	80	160	240
Cosden Oil & Chem., Col. Big Springs, Tex. (boiler feed)	79	742	821
City of Denton, Tex. (cooling)	80	100	180
Southwestern Pub. Serv. Co., Lubbock Tex. (cooling and boiler feed)	144	160	304
El Paso Prod. Co., Odessa, Tex. (cooling and boiler feed)	125	550	675
Texaco Inc., Amarillo, Tex. (cooling)	90	194	284

As shown here the cost of renovated wastewater is divided into two categories. The first is the cost of procuring the reclaimed water, including payments to the municipality, construction of effluent transportation facilities, and all other costs required to deliver the effluent to the industrial plant site. The second is the cost of treating the reclaimed water to make its quality suitable for the intended use.

The report also enumerated potential extra costs. These may be incurred when: 1) the effluent volume is insufficient; 2) increased treatment and water quality monitoring are necessary along with greater volume because the TDS of the reclaimed water allows fewer cycles through the cooling tower before discharge; 3) storage and transportation of the effluent is dependent on factors that include distance, elevation difference storage volume and pipe diameter; and 4) wastewater discharge may not meet regulatory standards. The cost to improve user effluent may be a deterrent to reuse.

In a report from Great Britain, Cox and Humphris (1976) showed that sewage effluent could be used for cooling water with complete confidence provided that certain guidelines are followed. The Croyden Power Station cooling system has successfully used nitrification in towers to control the pH and reduce alkalinity of municipal wastewater. There are at least eight other power generating or industrial sites in Great Britain where sewage effluent is used for cooling or makeup water. South Africa has also reported similar usage with only minor problems due to a change in the quality of the effluent before use (Flook, 1978). Israel, Japan and Mexico are known to use renovated wastewater for industrial purposes, as well.

Widespread use of renovated municipal wastewater by industry may be cause for alarm to some water suppliers whose business is dependent on the sale of water to manufacturers. However, a paper by Kollar and Brewer (1977) tends to allay these fears. According to their report, while wastewater reuse and in-house recycling will increase by the year 2000, reliance on public water supplies by industry will also increase. The reasons are twofold: 1) expansion of manufacturing will occur, and 2) water that is now being purchased by industry for process use is least likely to be affected by replacement with reclaimed wastewater. Food processing and textile manufacturing fall in this category.

Middleton (1977) recognized another facet of industrial wastewater reuse pertinent to this study:

> "In the U.S., it has been characteristic of industrial reuse that one plant only uses the effluent from a given sewage treatment plant. This occurs because the need for large volumes of cooling water and the one plant can be a significant fraction of the treatment plant output. The result is a very simple distribution system. Because of the cost of distribution systems, this tendency toward a small number of users, probably located close to the treatment plant, is likely to continue".

A reuse investigation in Denver, Colorado, however, indicated that while industrial reuse of wastewater may be logical, as in a case where a large coal-burning power plant is located within 2000 feet of the municipal wastewater treatment plant, it is not necessarily the most efficient method of procuring water (Heaton, 1978). This plant uses more that ten mgd of water, but the cost of the existing water source is about 30¢ per 1000 gallons cheaper than what it would cost to receive the same amount of equal quality reclaimed effluent. It is certainly true, as Heaton stated in this report, that "the industry cannot realistically be expected to convert to a more expensive source, even for public relations benefit."

Stone (1974), in a survey of attitudes toward reclaimed water, found that industrial managers were willing to accept lower contact uses, including industrial reuse of renovated effluent. This was a particularly important finding in light of the potentially tremendous market for reclaimed effluent. Koon, et al. (1973) stated that the attitudes of industrial workers, bearing on their willingness to cooperate in water conservation and reuse practices, may be determined by the relative emphasis management places on quality and conservation of water.

Linstedt (1971) reported on the applicability of wastewater reclamation for specific situations in Denver. This study: examined the possible beneficial uses of wastewater; determined the most favorable location for reclamation and the quality value of the wastewater; correlated water quality requirements with each beneficial use; and estimated public attitudes toward reuse of wastewater. This study, as in this project, identified the potential users, determined the quality requirements for each use, and described the attitudes of the users. Since all regions are unique, however, this study will identify the parameters pertinent to Massachusetts regarding wastewater reuse by industry.

CHAPTER III

METHODOLOGY

The study was directed to the industrial plants in Massachusetts using at least 100,000 gallons per day (gpd) of municipal water. Firms with private water supplies were not included. Public service individuals whose activities impact upon water resource planning in the Commonwealth comprised the second segment of the project's target population.

Interviews With Industrial Officials

The choice of industries was guided by a Massachusetts water usage study list of 'Major Water Users' (Curran Assoc., 1975). The list was amended throughout the study as further information was gathered, e.g. one company was contacted and subsequently included in the study upon suggestion of a participating industrial official. Hospitals, educational facilities and industries producing foodstuffs or sterile goods were not considered. These categories are unsuitable recipients of renovated wastewater under any conditions until national wastewater reuse research satisfactorily answers many questions about reclaimed water use.

A Directory of Massachusetts Manufacturers, (Geo. D. Hall Co., 1976) which lists company addresses and names of management personnel, was used to contact firms being considered for the research project. The Associated Industries of Massachusetts (AIM) provided assistance by suggesting names of key people to contact in some companies. Once an address list of selected industries was compiled AIM sent a letter to each, introducing the project, urging participation and assuring confidentiality of the data they may offer. For this reason the names of the industries contacted for this study will not be cited.

The AIM correspondence was followed by a brief letter from the investigators (Appendix 1) explaining the project to each industrial official on the list. A number of mailed responses were received indicating reluctance to participate, circumstances contra-indicating participation, notice that the letter was forwarded to another individual or answers to the sample questions and agreements to participate. Approximately five days after mailing the explanatory letter key individuals were contacted by telephone to ascertain whether participation by the particular industry was appropriate according to the criteria established at the outset of the study. This call also helped to identify the person ultimately interviewed. Numerous calls were often required before the correct individual, usually a plant engineer, plant manager or manager of environmental activities, was reached and an appointment time arranged.

Personal interviews guided by a questionnaire (Appendix 2) were conducted, with the investigator recording the responses. After the first three meetings the original questionnaire was slightly modified because one list item was unnecessary and two new questions could provide additional useful data. This new information was gathered from the original three interviewees in follow-up telephone calls. Such calls were also made if it was determined after an interview that clarification was needed or if there were gaps in the collected data.

There was no attempt to attain a statistical sampling of Massachusetts industries. Such a sampling was impossible due to the restriction of the types of industries of interest, the variability in quantity of water consumed and public information. Further, most manufacturing plants do not use municipal water supplies or use a combination of municipal and private sources. This reduced the number of available participants.

A report was written after each interview. This documentation assisted in recall of the details, identified the particular setting and highlighted aspects of the interview conversation pertinent to the research. These reports also helped the researchers recall the aggregate impressions of the industrial personnel.

Interviews with Public Officials

Twelve individuals working in public agencies concerned with water supply, water treatment or water resources planning were identified as potential participants in this study (Table 4). Again, a statistical representation was not possible. A goal of the research was to obtain opinions within various types of agencies rather than attempt to scientifically assess attitudes and the basis behind these attitudes.

As with the industrial officials, each public official was sent a letter explaining the nature of the study and requesting their participation (Appendix 3). When telephoned, all agreed to take part and arrangements were made for a meeting at the convenience of those involved.

TABLE 4: PARTICIPATING WATER RESOURCE AGENCIES

Metropolitan District Commission
Sewerage Division
Water Supply Division
Planning
Department of Environmental Quality Engineering
Division of Water Pollution Control
Division of Water Supply
Department of Environmental Management
Water Resources Commission
New England River Basins Commission
Environmental Protection Agency (Region I)
Massachusetts Association of Conservation Commissions

Occasionally more than one person participated in a discussion, or referrals were made to individuals who were considered able to provide information. As a result, interviews were held with twenty people in twelve agencies. All participants were personally interviewed with supplemental information from referred individuals gathered either by telephone or in person. For the purpose of analysis, cases in which more than one person was present during a discussion will be considered singularly as representation of one agency or division within an agency. When necessary, differences of opinion within group interviews were resolved by further discussion.

Each interview was guided by a list of prepared questions (Appendix 4). The procedure was not formal, however, and the conversation was allowed to flow in the direction indicated by the interviewee depending upon their expertise. Nevertheless, all of the questions were addressed unless the situation indicated otherwise. In some instances questions were excluded if the individual felt uncomfortable due to a lack of technical knowledge on the subject of wastewater reuse. If they had an unfavorable attitude toward the potential of effluent reuse by industry some questions were necessarily deleted. Occasionally, aspects not covered by the prepared questions surfaced. These points were documented and will be addressed.

A report to aid in the data analysis was written for each public agency interview, consolidating the essence of the remarks and opinions expressed.

CHAPTER IV

RESULTS

Responses from Industrial Officials

There are fewer Massachusetts industries using large quantities of water purchased from water purveyors than those with water rights to surface or groundwater sources. Of the 26 firms interviewed who buy water to supply their needs, fifteen (57.7 percent) receive water from the Metropolitan District Commission and eleven (42.3 percent) receive water from other water supply entities. Most of these industries use more than 100,000 gpd on an average daily basis with only four using the minimum 100,000 gpd as required by the study. There were seventeen participating industries (41.5 percent) that used more than 200,000 gpd of fresh water. Table 5 presents the quantities of water used by the industries represented in this study.

TABLE 5: AVERAGE AMOUNT OF WATER USED BY PARTICIPATING INDUSTRIES

Quantity (gpd)	Frequency	Percent
Approximately 100,000	4	15.4
125,000 to 160,000	5	19.2
200,000 to 650,000	11	38.5
1 million to 16 million	7	26.9
TOTAL	26	100.0

Half of the industries reported no variation in the amount of average daily water usage. Among those whose water intake was apt to vary, eight (61.5 percent of 13) claimed there were seasonal variations. Monthly or unpredictable variations each occurred in four (30.7 percent of 13) of the industries. Among the firms with a variable water intake, ten (76.9 percent of 13) reported the amount of variability was moderate. There was one incident each of a significant variation and of an insignificant variation in water usage.

Industrial officials were asked the quantities of water used for specific in-plant purposes and the water quality requirements for each use. A major function of industrial water is often for cooling purposes and, indeed, 21 firms (80.8 percent) reported that fresh water was used for this purpose. Of this group eleven (52.4 percent of 21) attributed more than 45 percent of their water usage to cool machinery, condensers, or the buildings.

The quality requirements that industrial officials claimed were necessary for water used as a coolant usually referred to elements causing scale and corrosion: a suitable level of total dissolved solids was mentioned by nine firms (42.8 percent of 21) and eight (38 percent of 21) stated that relatively soft water, i.e. control of hardness by low levels of calcium salts, was a requirement. Four of the industries (19 percent of 21) stated simply that cooling water must not be corrosive. A proper pH was required by five firms (23.8 percent of 21). The same number of industries cited temperature as a water quality requirement; water used for cooling necessarily being less than 70 degrees Fahrenheit. Two firms (9.5 percent of 21) required water having a low turbidity reading and one (4.8 percent of 21) needed water as pure as possible because of the sensitive nature of the items to be cooled.

The use of water for boiler feed was cited by half of the 26 plants involved in the study. Of these, three plants (23 percent of 13) used 50 percent or more of their incoming water for boiler makeup, and one plant used 38 percent of its total water supply for this purpose.

Water fed into boilers, usually made of cast iron, is turned into high temperature steam. Such heat creates stress if the water is not of sufficient purity. For this reason four industries (31 percent of 13) already pretreat water used for boiler makeup. One of these mentioned deionization as the method of pretreatment.

Two industries (15 percent of 13) cited low calcium salts as a water quality requirement for boiler feed and three (23 percent of 13) required water with a low level of total dissolved solids. Conductivity, low levels of suspended solids, water in which the pH was controlled and water of potable quality were mentioned by one industry each as other boiler feed requirements.

Water is also used in a variety of processes by twenty (76.9 percent) of the industries participating in this project. In twelve instances (60 percent of 20 firms) more than 35 percent of the total water intake was devoted to process use. Four firms used an estimated 0.8, 10, 20 and 30 percent of their water for processes, respectively.

The types of processes in which water may be used or consumed varied greatly among the industries, therefore, the water quality requirements were just as diverse. There were nine firms that stated water must be either: potable (20 percent of 20), deionized (15 percent of 20), as pure as possible (10 percent of 20), or approved as an ingredient in Federal Drug Administration products (10 percent of 20).

These same industries did not believe that using renovated wastewater for process use would be possible or acceptable.

Seven plants (35 percent of 20) required a water in which the pH was controlled as well as seven plants requiring suspended or dissolved solids controlled in process water. Six industries (30 percent of 20) claimed that metals would be harmful in their process water. There were two industries (10 percent of 20) unable to use water that was excessively hard. Control of odor, low levels of iron, control of microorganisms and water that was not corrosive were process water requirements cited by one industry each.

Four industries (15.4 percent) used water for the category 'other'. One of these used 80 percent of its average daily consumption for this purpose. The other three firms used less than 15 percent of their water for the purpose falling in this category. Only two of the industries indicated a water quality requirement for this purpose. One mentioned turbidity as a parameter of concern and the other required water that was not corrosive.

Wherever people work, water will be used for drinking, eating or sanitary purposes. Of the 26 industries participating in the study, however, only one (3.8 percent) consumed more than 50 percent of its total water intake for domestic purposes. Having accounted for this potable quality water, the amount used by this firm is still more than 200,000 gpd.

Most industries (73.1 percent) did not have water quality criteria established for any plant uses. Table 6 shows the number of industries that indicated criteria were set for various parameters. It was possible for an industry to identify more than one parameter.

TABLE 6: FREQUENCY OF WATER QUALITY CRITERIA USE

Parameter	Frequency	Percent of all industries
Microbiological contaminants	1	3.8
Total dissolved solids	2	7.7
Turbidity	1	3.8
Hardness	3	11.5
Heavy metals	2	7.7
Temperature	2	7.7
Other impurities (conductivity)	1	3.8

Degree of Acceptance

Having obtained this baseline information, industries were then asked whether they would accept the use of reclaimed water if it met their quality requirements. Eleven industries (42.3 percent) indicated they were willing to do so and six (23.1 percent) said they would accept such water under certain conditions. Nine industries (34.6 percent) indicated 'perhaps' they would agree to use reclaimed water. No industries indicated they would refuse to accept reclaimed water that met their standards.

The subject of economics was broached by asking if the company would be willing to pay the same price for reclaimed water that met drinking water standards as for the water they were presently receiving. There were nine industries (34.6 percent) that responded to this question affirmatively. Twelve industries (46.2 percent) answered negatively.

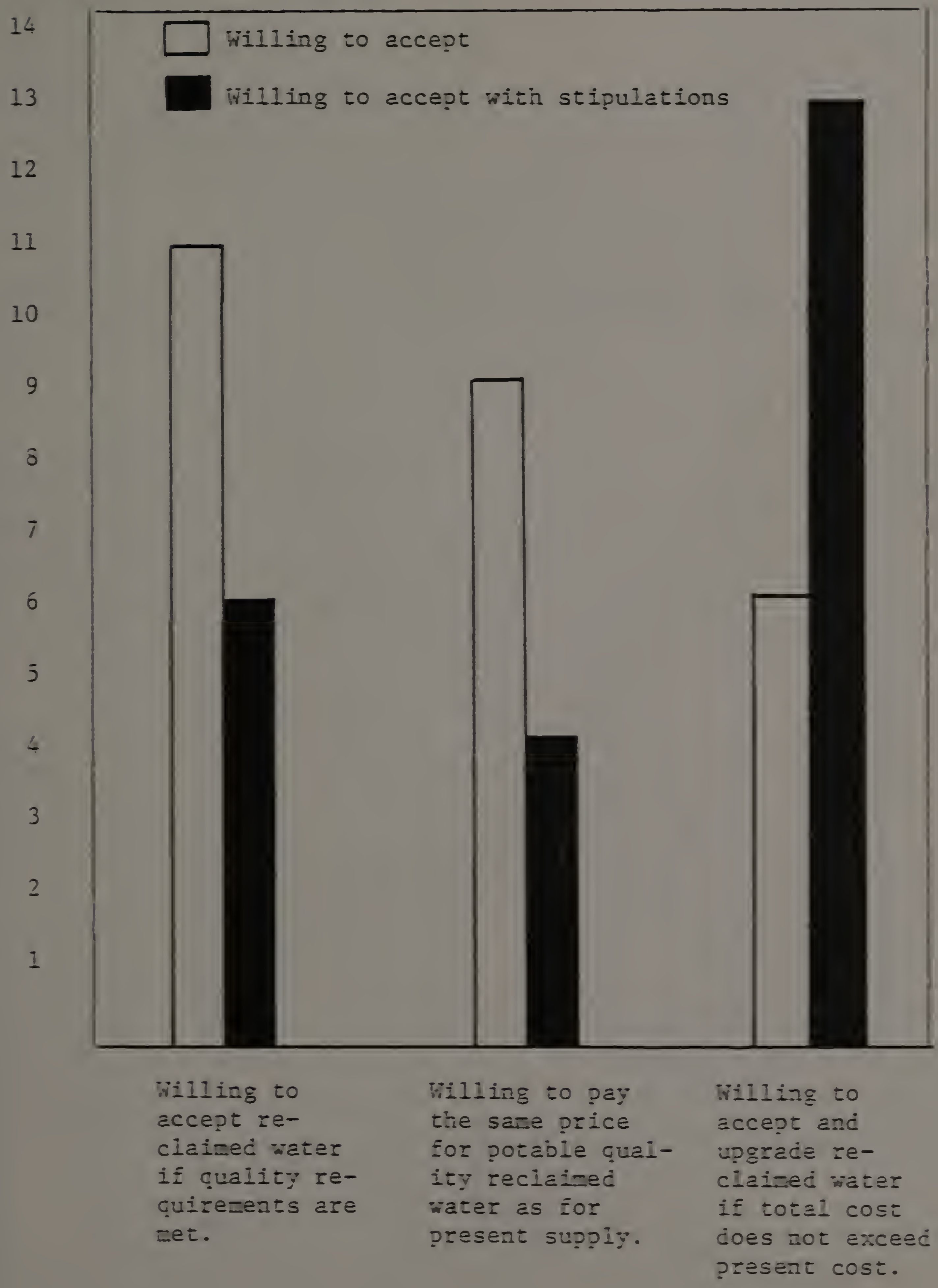
Four industrial officials, representing 15.4 percent, said their company would accept reclaimed water at the same price if certain stipulations were met. One individual categorized his firm's attitude as willing but unable to accept reclaimed water under those conditions.

Next, representatives were asked if their company would be willing to accept and upgrade renovated wastewater of a lesser quality than drinking water, assuming the total costs were not greater than their present costs. Of the 26 firms, 23.1 percent (6) claimed they were willing and 26.9 percent (7) were unwilling. Fifty percent of the industries would agree to this proposal if certain conditions were fulfilled.

Those industries that may be paying a user charge for sewerage service were asked if they would be willing to accept and upgrade reclaimed wastewater of lower than drinking water quality assuming the sum of the costs of the water, its treatment and of the sewer use charge did not exceed their present cost for water and sewerage service. There were fourteen firms that responded, half of which said they would be willing to accept renovated wastewater under such circumstances. Three of the fourteen industries (21.4 percent) were not willing to accept water as proposed and four (28.6 percent) claimed the total costs would definitely exceed the company's present water and sewerage costs.

Figure 1 shows the number of industrial officials that indicated they would accept reclaimed water under the conditions specified in the three preceeding questions. The frequency of those willing to accept reclaimed water with certain stipulations, such as a guaranteed return on investment within five years, or assurance of a quality

FIGURE 1: FREQUENCY OF INDUSTRIES WILLING TO ACCEPT RECLAIMED WATER



controlled supply, changed according to the limitations attached to the hypothetical situation. More than three times as many firms attached stipulations if they accepted effluent needing further treatment than those that attached stipulations if they accepted sufficiently treated effluent.

The industrial representatives were next asked what economic incentives they thought were feasible to encourage the use of reclaimed water by industry. Answers to this question included the stipulations some of the respondents required in the preceding questions. More than one answer was acceptable per respondent. The replies are grouped in eight categories.

The most frequently cited economic incentive (nine firms; 34.6 percent) was to have water and sewerage charges decreased if reclaimed water were used. Six industries (23.1 percent) stated that if the cost of the renovated effluent were significantly less than the cost of their current water supply they might seriously consider the use of reclaimed water. Five industries (19.2 percent) indicated that tax breaks or sizeable tax deductions were incentives, and the same number considered the minimization of possible risks, such as cross-connections or decline in the quality of the water, as an incentive.

Four respondents would require a profitable rate of return if they were to invest in a wastewater reuse project. Industries usually expect this return within two to five years, although two of these firms said this could be extended because such a project would be considered a public service. Because wastewater reuse projects are likely to be extremely expensive, three industries (11.5 percent) cited federal construction grants as necessities to encourage them to use reclaimed water. There were two industries each that cited two other economic incentives. These were (1) financing of the dual piping system by outside sources and (2) an incentive because water and/or sewerage costs were sharply increasing.

Industrial Attitudes Toward Water Conservation

Respondents were asked if they believed the use of reclaimed water by industry is a promising method of conserving water. A majority of industrial officials (73 percent) agreed that the use of reclaimed water could conserve some fresh water, but 88.8 percent of these (16 out of 18) attached clarifying statements.

One such statement expressed by eleven individuals (61 percent of 18) was that water recycling was superior to reuse for conservation purposes. Eight of these eleven respondents already have water recycling systems operating within their plant. These eight are among the 22 (84.6 percent) industries that recycle water. Two other industries indicated that such a project was being considered by their firm.

Other clarifying statements include the need for economic feasibility in order for wastewater reuse to be viable water conservation technique (four respondents), and the need for an industry to be close to the sewage treatment plant providing the renovated water (one respondent).

There were seven respondents (26.9 percent) who did not believe the use of reclaimed water by industry would sufficiently conserve water. Five of these individuals preferred other methods, such as recycling. Indeed, four of these industries recycle water and one was considering such a water saving scheme. Two other respondents did not believe there was a scarcity of fresh water, negating the need for wastewater reuse projects.

Fourteen industries (53.8 percent) reported they have adopted water conservation policies. Seven firms have passive policies (operation of cooling towers) and one other firm is considering a water conservation plan. Four industries were putting no effort toward reducing their water use.

The final question posed to industries asked the feasibility of constructing a dual water distribution system within their plant to accomodate two water supplies. Half of the industries (13) stated that installing a dual water system was feasible and 11.5 percent (3) that their facilities were too old and expansive to accomodate a dual piping system. In 38.5 percent of the industries (10) a dual system would be feasible with difficulty, again because of size or the existing physical conditions.

Attitudes of Public Officials

The two major concerns about wastewater reuse in Massachusetts raised during interviews with water resource officials were: a) whether they believed the concept has potential as a means of supplying industry with some of their water needs, and b) whether supplanting water used by industry with renovated wastewater has promise as a means of conserving fresh water supplies. The distribution of responses to these issues are identified in Table 7.

TABLE 7: PUBLIC OFFICIALS' PERSPECTIVES ON WASTEWATER REUSE

Hypothesis	Yes	Undecided	No
Wastewater reuse by industry has potential in Massachusetts	6	-	6
Wastewater reuse by industry is an effective water conservation measure for Massachusetts	1	3	8

Responses to the first concept were evenly divided among the twelve respondents; six disagreed there is a potential for wastewater reuse and six ageed there is a place for reuse in the future. These individuals will be considered either to be favorable or unfavorable toward the concept of reuse by industry. Table 8 summarizes responses to this concept according to the supplemental information provided by the interviewees.

TABLE 8: CHARACTERIZATION OF PUBLIC OFFICIAL' ATTITUDES TOWARD THE POTENTIAL FOR WASTEWATER REUSE BY INDUSTRY

	Attitude			
	Favorable*		Unfavorable*	
Clarifying Statement	Slightly	Very	Slightly	Very
Should be considered in the near future	2	1		
Technical capability exists	4	2		
Technical capability does not exist				1
Could occur under certain conditions	2	1	2	2
Would not be cost-effective	1		3	1
MDC unable to accomodate			2	2
Unnecessary measure			1	2
Overall attitude toward the potential for wastewater reuse	4	2	4	2

*N = 6

Those who were favorable toward reuse ranged in assuredness. Two individuals strongly believed renovated effluent could be of use in the Commonwealth. Four others expressed some faith that reuse was a viable concept needing more attention and research. One individual, very favorable toward reuse, as well as two who were slightly favorable, thought that reuse should be considered in the near future. Half of those favorable toward reuse accepted it if certain conditions were fulfilled. These requirements included proof of cost-effectiveness and safeguards such as prevention of cross-connections, adverse health effects, and other possible adverse secondary impacts. All of the individuals favorable to the concept believed that the technical capability exists to provide industries with renovated effluent that will meet their respective needs. It was noted that more intensive examination was needed to accomplish this practically and with quality assurance.

The degree to which six individuals were unfavorable toward reuse varied also. One person, slightly unfavorable, confessed to have little knowledge on the subject but, based on what was known, seriously doubted its viability. Two individuals, both engineers with many years experience in water resources, saw absolutely no potential for reuse in the Commonwealth.

Four individuals with unfavorable attitudes did concede that the situation could exist in the future where there may be a limited role to be fulfilled by renovated wastewater. Reasons ranged from imagining reuse possibly performing a very limited and restricted role to skepticism that they could assess the future with any certainty.

Only one of the six individuals unfavorable toward reuse thought that such a project could be cost-effective. A further concern expressed by three individuals in a group interview, and alluded to by three other respondents, was the inability of the MDC sewerage system to accomodate wastewater renovation without extensive engineering modifications. (The MDC sewerage system was considered a logical target for a reuse project, although this would not necessarily be true.) A change in philosophy of those operating this system would also be extremely difficult to obtain. One respondent noted that the Bay State is not geared to undertake such a scheme because it necessitates widespread acceptance by public officials, industrial people and the general public. Further, the individual noted that the lack of a functioning State water resource plan would also hamper efforts to institute a reuse program.

One strongly unfavorable participant did not believe that secondary effluent, nor any effluent given the expected cost of advanced treatment, was suitable for either cooling purposes or process water. This person's unfavorable attitude toward reuse was largely based on this fact, as well as beliefs of prohibitive costs and the inconvenience necessary repiping to handle renovated wastewater entailed. This latter viewpoint was shared by three others unfavorable toward reuse as well as one respondent with a favorable attitude. Another participant cited wastewater treatment system unreliability as one reason for not accepting reuse.

The major reason for three unfavorable opinions toward municipal effluent reuse, two of these held by those strongly in disagreement, was due to the belief that such an extreme measure to provide water is not necessary. These individuals see Massachusetts having potential fresh water supplies available for at least thirty to fifty years. As the region has successfully been able to cope with increasing demands in the past, largely by constructing interbasin water transferral systems, these individuals saw no reason to doubt such success in the future. One individual estimated that undeveloped supplies are double the presently available State supplies. Further, it was once mentioned that the region has never experienced a drought severe enough to stress the water supply system beyond its capabilities according to precipitation records that date back well into the 1700's.

Associated with the unfavorable attitudes is the belief that wastewater reuse is incapable of conserving sufficient quantities of fresh water to justify its development. As indicated in Table 7, only one respondent in twelve agreed that reuse of effluent by industry would be an effective water conservation measure. Even though industries are using millions of gallons of water each day for purposes that could use lower quality water, the spectre of a 1975 report (Curran Assoc., 1975) identifying leakage and faulty metering still lurks in the minds of officials who realize and who mentioned that elimination of these conditions would do much to contribute to water conservation.

Two of the officials interviewed did not view water conservation as an important issue. Rather, one individual stated that all water demands could be met and the other that wise use, versus non-use, which conservation implies was more prudent.

Others disagreed as to how conservation could best be accomplished, with eight respondents doubting that reuse by industry would effectively reduce water demand. Two individuals thought that efforts aimed toward the domenstic sector were more likely to yield significant results because of the ease of implementation. Two respondents thought a recycling system utilizing cooling towers would reduce water consumption more efficiently.

The basis of opinion for the respondent strongly agreeing that reuse could effectively conserve water was in direct opposition to this former argument. Data was cited indicating that totally successful conservation measures on the part of households, who consume 24 percent of fresh water supplies, could not substantially reduce this demand. Industrial and commerical sectors, however, were noted to consume 43 percent of the total water supply. It was predicted that a large part of this demand was flexible enough to dramatically respond to the right conservation stimuli. Unpublished data from the City of Springfield was cited as an example. Municipal wastewater effluent reuse was considered by the respondent to be capable of becoming such a stimulus.

This individual also believed that changes in fee structures has great potential for reducing water demand and enhancing the likelihood of reuse projects. This was also mentioned by five other participants, one neutral toward the idea of reuse as a conservation measure, with the other four disagreeing that reuse would substantially conserve water.

Another respondent suggested that effective conservation attempts are more likely to succeed if they directly relate to the consumer's needs. Often, such needs may not be considered linked to water. Public relations and a firm's civic pride could fall into this category. In this light, reuse may fulfill some role, but other measures requiring less investment were considered as more promising in order to conserve resources.

Two respondents considered the relatively small quantities of fresh water that Massachusetts industries consume insufficient to justify reuse programs. One of these people estimated that a ten to twenty mgd demand was necessary to support reuse by industry. The other noted the distance of firms from sewage treatment plants as a handicap.

A respondent neutral toward reuse as an efficacious means of conservation noted that a water saving program is not the total answer to a water supply shortage, just as rate changes or zoning cannot singularly solve a supply problem. These planning tools were seen as elements that work together in a complex formula that can aid in better resource management.

The economic outlook of a municipal effluent scheme is a major factor relating to its potential as an industrial water source. This fact was often brought up in the discussions with public officials even before it was mentioned by the interviewer. It was unanimously considered that economic matters would be thoroughly scrutinized, even though perplexing, when reuse is considered in Massachusetts. Further, three respondents believed it unlikely that reuse by industry could ever be cost-effective. One individual remarked that it would obviously be less expensive to install a reuse system in a plant under construction than in an existing manufacturing plant.

All respondents anticipated high costs would hamper providing reclaimed water to industries. The costs to install a dual piping system from treatment plant to an industry, with safeguards, and the cost within the plant, were mentioned as considerations of prime importance. Energy costs to pump the effluent and the costs to upgrade its treatment to the desired level were considered pertinent. Maintenance and administrative needs were also deemed costly by two respondents.

Naturally, the locale of an industry relative to a sewage treatment plant would have a financial impact on a reuse project; the greater the proximity the less costly the system. Four respondents volunteered this factor as one to consider, with one individual doubting financial viability of a project if the distance between firm and treatment plant were greater than 200 feet. In three instances, newly developed industrial parks were considered especially good potential recipients of renovated effluent. This situation would consolidate the area in which new piping would be placed as well as eliminating destruction of existing facilities to incorporate a dual system. The close proximity of such a park to a sewage treatment plant would, of course, be required.

Who the interviewee considered financially responsible for additional upgrading of effluent and piping, was a question intimating a complex answer. One agency official noted that this issue needed close attention and that the solution was unclear because of the theoretical nature of the discussion. Three individuals stated that the industries were clearly responsible because they would be the users of the facilities. Four other individuals thought that the financing would be more equitable if cost-sharing between governmental agencies and industries occurred. These same people also believed that the federal government should at least partially fund local reuse projects because of the great expenses involved. Four of those interviewed could not speculate upon where the financial responsibility might lie, and none of the respondents stated that state government should bear the full financial burden.

When asked what economic incentives might be appropriate with respect to the applicable cost of a reclaimed wastewater distribution system, three individuals stated that this could be demonstrated by some means of tax relief. Outright funding grants were also noted as an inducement. One person stated that substantial subsidies would be essential to the viability of a reuse project. Officials in five agencies could offer no suggestion for economic incentives.

The situation of investment in a reuse system becoming a financially viable water supply alternative was mentioned within four of the agencies interviewed. The individuals indicated that a reclaimed water use project could become an attractive opportunity if other water related costs substantially increase in the future. The predicted higher costs of fresh water, coupled with pretreatment fees or industrial cost recovery fees currently being collected by EPA, could create an automatic incentive to examine reuse possibilities more closely. They all noted that if water were priced at its true cost, use of renovated water would be enhanced; the price differential would be less than it is with fresh water at current prices. As previously noted, the need for a change in water price structuring was an unsolicited remark offered by fifty percent of those interviewed.

Demonstration projects were mentioned by three respondents as particularly good incentives. They noted that if a successful pilot project were to be built, raw data would be available so that officials and industries could make knowledgeable assessments. Economic and technical aspects could be presented and hopefully serve to allay the fears of municipal works engineers, public agency personnel, industrial employees and the general public. Proof that reuse can be practiced in the Commonwealth would enhance acceptability.

Indeed, three respondents had concern for a potential negative public response due to an adverse psychological impact reuse projects may generate. One of these individuals suspected psychological reasons, similar to those involved with the fluoridation issue, may cause the general public to oppose the use of reclaimed water. Psychological repulsion exhibited by union workers faced with working in an environment where reuse of wastewater occurs was mentioned by another individual. The third person with a concern for psychological impacts predicted resistance from public officials working in the field of water resources.

While only one individual expressed a grave concern for the threat unknown aspects of wastewater reuse may have on the health of the general public, this same person, as well as three others, expressed a fear of cross-connections and what they imply. The necessity of a dual water supply gave these people cause to suspect that contamination of potable water, either within the industry utilizing renovated effluent or outside of the industrial site, was possible. Two of these individuals approved of the wastewater reuse concept in Massachusetts and two disapproved.

CHAPTER V

DISCUSSION

As the literature review indicates, there have been many years of practical experience regarding the direct use of wastewater by industry. Why this practice is not more prevalent, particularly in light of increased water shortages, is of prime concern. This research has been an attempt to answer that question and to provide additional information as it relates to Massachusetts.

Results of the survey indicate a serious hesitancy to embrace reuse by both industry and the public management/regulatory sector. However, to conclude that reuse of wastewater by industry is untenable in Massachusetts would be just as erroneous as to project great hope for the reuse potential. A thorough examination of the factors involved is necessary.

Theoretically, a project proposal such as the reuse of water by industry must pass four feasibility tests for it to be properly evaluated. Indications as a result of this research pertaining to social, economic, political and engineering feasibility tests will be discussed in order to evaluate the potential of renovated wastewater use by Massachusetts industries.

The test of social feasibility is passed if those affected are motivated to accept the benefits reuse may offer. This study accomplished a partial assessment of potential industrial recipients of reclaimed wastewater by exploring attitudes.

Methodologies to assess attitudes and beliefs are numerous. Attitude theory research spans decades and measurement techniques have been modified as knowledge increases. This project was not designed to experimentally determine the basis for attitudes toward wastewater reuse. Rather, its purpose was to gain a general understanding of the prospectus of industry utilizing reclaimed wastewater by documenting attitudes that exist and compiling industrial water quality data. Nevertheless, attitude theory can offer some explanation for the results of this study and is worthy of discussion.

Attitude Theory as it Relates to Wastewater Reuse

What a person believes about the concept of reclaimed water will be in congruity with the formation of his or her attitudes and behavior as they relate to wastewater reclamation. This is based upon a theory proposed by Osgood and Tannenbaum (1955) who discussed congruence and combinations of stimuli. This congruity principle can be applied for comprehension of water reclamation attitudes by using a three-tiered structure of beliefs. The first tier recognizes that some people's beliefs will be consistent with the acceptance of renovated wastewater usage and will therefore be no hindrance to the adoption of its use. The next level show that other beliefs, some unfavorable toward reuse and perhaps inaccurate, can be altered through education. These information programs can result in a greater portion of the population becoming favorable toward reuse as they attain a new belief-attitude pattern attributable to acceptance of acquired knowledge.

Still other beliefs, such as those based upon inherent personality factors and emotions, and the basis for why these beliefs are held, is the third tier which has barely been explored by researchers of public attitudes toward reclaimed water. Olson and Pratte (1978) hypothesized that psychological factors play a large role in the formation of these types of attitudes. They identified a flexible attitude toward change, and faith in technology as two factors indicative of a favorable attitude toward reclaimed water, particularly if it is to be used for non-contact uses such as may be applicable for industrial purposes.

Katz (1960) has used the functional approach to explain the reasons people have the attitudes they do. He contended that these reasons are psychologically motivated and are not accidents of external events and circumstances. Furthermore, the psychological need which is met by the holding of an attitude must be known in order to predict how it will change. If attitudes toward reclaimed water can be ascertained according to the needs that are served by the individual holding that attitude, then the conditions and techniques for attitude change can be predicted. These factors must be understood in order to achieve acceptance of renovated wastewater via educational tactics. These tactics will become more complex if the attitude is tied to a value system which is closely related to a person's conception of him or herself. Value systems are considerably independent of education level or economic status (external circumstances) and should be closely considered when appraising motivation for attitudes toward reclaimed water.

Katz's four functional modes further reveal parallels to attitudes that have been described, but not thoroughly explored by researchers of attitudes toward reuse of water. The first function described attitudes as dependent upon the past or present perception of the utility of the attitude object. Clarity, consistency and nearness were seen as important factors in the acquisition of an attitude. They are formed as needs are satisfied. Katz hypothesized that "the closer objects (attitudes) are to actual need satisfaction and the more they are more clearly perceived as relevant to the need satisfaction, the greater the probability of positive attitude formation." In this research, where fifteen percent of the public officials had both an unfavorable attitude toward reuse and did not believe there was a scarcity of water warrenting the reuse of sewage effluent, it may be hypothesized according to Katz's postulate that these individuals will not realize the benefit of exploring the potential for reuse by industry until they learn of Massachusetts' water problems.

Ego-defense, Katz's second mode of attitude formation, involves a reduction of anxiety as a reason for holding an attitude. This function describes attitude development as a result of a person's emotional conflicts. Fluoridation of public drinking water, and possibly reclaimed water usage, may be used as targets by some to vent their feelings of alienation and lack of defense against a bureaucratic system. Industrial official respondents of this study may have unwittingly activated an ego-defense mechanism when they required federal or state support of a project before accepting reuse. Many believe there is an excess of industrial discharge regulations and may see regulations for reuse of wastewater being another facet over which they will have little control. By rejecting the notion, unless there is outside responsibility, anxiety is reduced.

Value expression, the third functional category of attitude formation, is an expression of personality type. This may be a better indication of reasons for favorably or unfavorably supporting the potential for wastewater reuse than a socio-economic scale which has been traditionally used and relied upon as significantly correlated to attitude tendencies. This research made no attempt to assess either personality or socio-economic status.

Knowledge is the fourth dimension of a functional basis for attitude formation and perhaps the most relevant for the investigation at hand. It presupposes that the understanding of a concept introduces stability that is provided by the norms of one's culture. People want to understand events which directly impinge on their own life. A lack of comprehension may be displayed by negative attitudes toward an unfamiliar subject such as wastewater reuse.

Biswas (1963) believed that an individual's perception and attitudes are strongly influenced by the culture in which he lives. He added that the experience a person has previously encountered, the situation confronting him at any one point in time, and the role he plays, or is expected to play, as a member of the system affects individual decision and attitude formation processes. This theory offers an explanation for the unfavorable attitudes toward reuse from industrial and water resources officials in Massachusetts, where deliberate wastewater reuse does not occur. The future situation of water resources in the New England region is unclear to industrial officials and even to individuals who are attempting to plan for increased supplies. It is not surprising that they are unwilling to heartily embrace a concept that is without precedence or has a proven need.

Further, it was obvious during the personal interviews that the individuals working within industry were more willing to express a definite attitude than some of the public sector respondents. As Biswas confirms, their role within the system affected their attitudes. Whether the public officials offered their true attitudes can never be known, and the degree to which their responses were politically motivated will remain equally obscure.

A number of wastewater reuse attitude studies have cited that the objection to the use of reclaimed water as a viable alternative to a water shortage lies with resource officials, not with the public (Johnson, 1971, Sewell, 1971, Owen, 1968). They all indicated that water managers, public health officials and consulting engineers believe the public is overwhelmingly opposed to the use of renovated wastewater when, in actuality, these officials know very little of true consumer opinion. Evidence of national interest and an increase in wastewater renovation research indicates that provincial Massachusetts has yet to become enlightened regarding national activities, however.

The studies cited above similarly conclude that it is the conservation training of individuals in the water management business which fosters disregard for wastewater reuse. Conditioning throughout their training has promoted satisfaction with past policies and practices, with few alterations ever suggested. Further, Sewell (1971) noted that contact with representatives of other agencies, e.g. water supply professionals to wastewater officials, or with the general public, is considered unnecessary or potentially harmful.

Attitudes such as these must first be detected, then dispelled if progress is to reign for water resources management. Facts must be examined objectively and the inherent biases of the regional planning individuals must be recognized in order to discover the opportunities available as solutions to a pressing problem. While wastewater reuse by industry may not ultimately be a viable alternative, it would be foolhardy to dismiss the concept without sound reason.

Economic Considerations Concerning Wastewater Reuse

Economic factors play an important role in evaluating the potential of reclaimed water usage by industry. No matter how altruistic management's beliefs toward water conservation or the preservation of water quality may be, the business operates to make a profit. The acceptability of reuse will be determined largely by the economic advantage it confers.

All industrial officials regarded a favorable economic outcome as the basis for their acceptance or rejection of reuse, yet few could delineate all of the contributing factors that legitimately indicate the economic viability of a reuse scheme. This section will explore economic aspects that may inhibit and/or contribute to feasibility and thus the potential for industrial wastewater reuse.

Economic feasibility can be viewed from either the perspective of an individual industry or from that of society as a whole. From a societal perspective, the economic feasibility test is passed if the total benefits that accrue as a result of reuse, exceed its cost. Further, economic optimality occurs when the difference between benefits and cost is maximized. Economic feasibility, however, also depends upon engineering feasibility and design. For now it will be assumed that the engineering capability exists for wastewater renovation. This will be discussed in greater detail in another section.

Additional aspects of an economic nature contribute to economic feasibility. One, price of the renovated wastewater, was the parameter considered most frequently by industry, yet price of water is a deceiving factor. Milliman stated that "the economic costs of urban water supplies have been very low in relation to its worth in domestic, commerical and industrial use." (1963) This implies that the government may be the ultimate financier of water resources projects. And, as Collins (1977) observed with regard to the construction of secondary sewage treatment plants since the advent of P.L. 92-500, it is the middle income class of taxpayers who often bear the burden of government investment programs. He also calculated that industry typically receives a subsidy which is greater than that received by municipalities if they share a treatment facility.

It can therefore be assumed that an industry using a municipal water supply, usually in much greater volumes than domestic users, may receive a substantial subsidy as well. The declining block rate structure, used in an estimated 80 percent of American cities - Massachusetts communities among them - favors large water users and increases their share of the subsidy.

This subsidy is likely to result from funds borrowed for water supply project construction at a lower interest rate than the average interest rate paid on long-term government bonds. The subsidy equals the difference between the cost of current borrowing and the lower interest rate of the project. Those served by federally backed water supply projects pay less than the full marginal cost - the cost to supply the incremental unit. Inefficient use of water is thereby encouraged because it is priced below cost. It follows that subsidies can ultimately act against water conservation.

Policies such as price subsidizing have led to the fundamental misconception that pervades the water industry and termed by Milliman

(1963) as the "water is different" philosophy. This philosophy connotes that water is unique and should not be treated as an economic good. The failure to use basic economic theory becomes apparent when examining the methods by which water demand has been projected and pricing policy determined. The true value of an assured future water supply, and the cost to construct, maintain and transport water, have been traditionally left out of the price people and firms actually pay. By charging an artificially low price for municipal water, inefficient use is promoted and an articicially inflated demand is projected. Future demands, which are the basis for new water supply projects, may also be miscalculated.

<u>The use of cost/benefit analyses</u>. It was noted by respondents that acceptability of reuse could not be reliably estimated without a cost/benefit study. A benefit-cost analysis is one formal test of economic feasibility, which assumes that the current use patterns will continue. The practice has been extended to all federal water resource development plans since the Flood Control Act of 1936 (U.S. Flood Control Act). Since then arguments and accolades concerning this "art" have been heard, and private firms and state governments continue to perform such analyses on water and other types of projects. The point of a cost/benefit analysis is to objectively evaluate the merits of a project to determine whether the allocation of funds is justified. However, thorough and proper identification of both project costs and gains is a very difficult task.

Unfortunately, there is no documented evidence available to date, of a cost/benefit analysis on a wastewater reuse project. It would seem logical that wastewater reuse under certain conditions is economical, otherwise existing projects would not have been developed. Yet, the true value of economic feasibility is very unclear. As Milliman stated, "It is an interesting commentary on the rapid development of the science and technology of wastewater reclamation that apparently so little attention has been paid to the basic economic factors influencing the feasibility of reuse on urban wastewater." (1978)

Is this one reason reuse by industry is not widely practiced? Perhaps the inability of an industry to capture the full benefits of a reuse project is a barrier to reuse. For example, a portion of the benefits, such as the value of increased potable water supplies to the regional population, may not accrue to the industry. Furthermore, investment in a water supply project - in this instance a reuse plan - is obviously a long-run venture. As emphasized by several industrial respondents, firms are geared to plan financially in the short-run, demanding a two to five year return on investment. This indicates reuse projects may inherently require that governmental entities bear a large burden of the costs.

A cost/benefit analysis must be performed in relation to the specific industry or industries that may potentially receive wastewater effluent. The resulting ratio would usually vary from site to site, depending on the type, size and layout of the plant, water quality requirements, amount of effluent demanded and other factors. For this reason, there is no assurance that reuse is feasible until a detailed analysis has been performed.

Preparation of a cost/benefit study. Reliable cost/benefit studies are difficult to prepare. A wastewater reuse project study may be further complicated because both the water provider and the water pollution control agency are necessarily involved. It is possible that each agency will produce its own population growth estimates, demand projections, temporal supply capabilities, and cost estimates including operation and maintenance, and that these may vary. To perform a cost/benefit analysis on such a project requires use of a common data base by concerned civil engineers, planners, social ecologists and environmental health specialists.

The benefit/cost study would require several levels of analysis. First, if there are a variety of alternative project sizes or designs, a number of factors must be considered including: location of the treatment plant in relation to the potential reclaimed effluent recipient, volumes of water to be treated and used, treatment process that is to be employed, changes to the treatment plant that may be necessary, and legal considerations such as clean water standards and discharge restrictions. From this evaluation, alternative reuse projects could be identified. For example, one alternative might be reuse at industries A, B and C; another might be reuse at industry B with potable water provided for domestic use. These alternatives can then be analyzed in terms of a cost/benefit comparison. Differences between the amount and characteristics of potable water and those of the reclaimed water will have a bearing on the measure of benefits.

Costs to the municipality and the industry, and the benefits to each must be itemized. Costs to the municipality include those to reclaim the wastewater. If the treatment plant is to provide water for a variety of industries, their quality requirements will influence the degree of necessary treatment. Optimally, industries will be served that have water quality requirements which can be met by secondary treatment alone. This may negate the need for treatment beyond that which the municipality is already providing. If further treatment is unnecessary, the cost to treat can be considered zero. Additional cost, however, would be incurred to reduce risk of treatment plant failure. This would cover employment of additional, trained and experienced operators and use of sensitive monitoring and control equipment. Storage facilities needed in order to provide water during off peak periods may also add to the list of cost items. Administrative costs for billing and supervising are additional items to be included.

The cost to construct facilities that will transport renovated wastewater to industries will be the bulk of the expenditures. These estimates must consider planning, design, construction, including labor and materials, inspection and finishing costs, i.e. attorney fees. Beyond this is the additional costs associated with reducing the inconveniences involved.

Costs to the user will include those for extra treatment that may be necessary, adaptations to equipment for conveyance within a plant and for storage. If more reclaimed water is used than potable water previously used, the reuser may incur additional costs for discharging higher volumes of wastewater.

Benefits to the community are numerous but difficult to quantify. The major difficulty with estimating benefits is the problem of designating monetary values to each. The volume of renovated water used can be considered a savings in potable water not consumed, and thus reduce the needs for the future. And, as water conservation is a basic goal of the project, this item will carry considerable weight when quantifying benefits.

Benefits to industry include the potential lower costs for water, long-term assurance of supply, and possible enhanced public image. Because of the difficulty in grappling with non-quantifiables, the full spectrum of possible benefits is easily overlooked. Research opportunities, increase in the credibility of reuse, and regional adaptability are aspects that are difficult to quantify yet necessary to analyze.

If all benefits can not be evaluated in monetary terms, perhaps a more practical method of presenting results for use by decisionmakers might be to initially offer an explanation of the shortcomings of cost/benefit analyses in regard to situations that are heavily dependent upon social variables (non-quantifiables). Following a technical assessment of the quantifiable variables, a table such as the following might be presented.

TABLE 9: COSTS AND BENEFITS NOT QUANTIFIED*

costs	benefits
Potential of industrial work stoppage due to cross-connection mishap	Reduction of costs and environmental damage from the construction of smaller water supply systems (reservoirs, treatment facilities,etc.) than otherwise required in the absense of reuse
Opportunity costs of alternative investments	Improved quality of water which previously received wastewater effluents
In plant inconvenience and work slowdown due to construction activities	Increased employment opportunities
	More favorable public view of industry due to perceived concern with water conservation and the environment

*Modelled after a similar table by Stone, Wastewater Reclamation: Socio-economics, Technology and Public Acceptance, p. VI-39.

The analysis can also offer decisionmakers choices among alternative time periods for investment and construction. If demand, price of water to customers, and cost figures can be confidently determined and are acceptable to the officials involved, the optimal time for investment can be calculated. Benefits as well as costs change over time. A cost/benefit study may well indicate the time for wastewater reuse by industry in Massachusetts will not be appropriate for a decade or more.

The water resource planner may expect the reuse system to be incorporated into a large regional treatment plant. In Massachusetts, the MDC has examined the engineering feasibility of constructing a secondary sewage treatment plant on Deer Island in Boston Harbor to conform with the national Water Pollution Control Act Amendments. An economy of scale is accomplished by having the one plant serve the entire, expansive system.

Pursuing avenues to accomplish economies of scale may not always be the most advantageous if a multi-purpose water treatment facility is intended, however. In exchange for lower operating and maintenance costs inherent in a single regional sewage treatment plant, smaller upstream satellite plants located along existing interceptors, not only optimize use of existing pipelines, but can be designed to reclaim water for use in the immediate vicinity. Excess flow and all solids are returned to the interceptor line for treatment at the regional plant. Advantages may arise (translated into benefits within a cost/benefit analysis) with the concentration of sludge handling located at a single site; the regional plant. Such a situation exists in the Los Angeles County Sanitation District, which is engaged in a massive wastewater reuse planning project, and is being considered for the Phoenix, Arizona metropolitan area where the potential demand for effluent far exceeds the possible supply.

This type of scheme also helps to justify the billions of federal dollars that have been spent on local secondary treatment plants. If each community is to have their own facility, maximization of its use ought to be attempted.

Often the future demand for water is calculated by a simple extrapolation of the requirements of current domestic, industrial, commercial, municipal and agricultural uses of water. If the planner views the amount to be consumed as a fixed amount, ignoring the relationship between per capita demand and price, serious errors may be made in projecting demand. It is very apparent from the emphasis the nation is placing on water conservation, that these factors must be considered in future water supply plans.

Further, it makes no sense to estimate future demand based on present consumption of inexpensive water. Projects supplying future needs will increase the cost to provide water and may result in higher consumer prices. Economic theory indicates such prices will shift demand to lower levels. It is no wonder that project proposals based on the requirements approach of present consumption indicate a severe water shortage.

Whether water user fees are below true cost of supply now or in the future, prices not reflective of true water costs may present an obstacle to reuse. As the results indicate, industries will base their acceptance or rejection on a reuse project in a comparison of the price of their current supply to the renovated water. Frequently the cost of reclaimed water exceeds the price charged for existing supplies. This conparison is deceptive if it is interpreted to mean that reuse is economically infeasible, since the price of existing supplies is frequently below its true economic cost.

For these reasons, careful examination of the options available to industry and to decisionmakers, based on sound economic theory, deserve attention. A cost/benefit analysis is a method that can objectively compare the options available.

The Political and Institutional Aspects of Wastewater Reuse

Water projects are often controversial. Issues totally outside the realm of water supply may emerge in public discussion or private planning of a water reuse project and dramatically affect the final result. Identification of these extraneous issues is impossible. However, discussion can be directed to the political issues and institutional aspects which are recognized as having an impact upon the potential for the advent of municipal sewage effluent reclamation and reuse. These factors largely comprise the political feasibility of reuse and will be considered here within the context of institutional, legal and general issue constraints.

One particular Massachusetts issue can be cited as an example where the politics behind alternative plans for water supply can enhance or detract from a reuse project. Diversion of the Connecticut River during peak flows to the Quabbin Reservoir to provide metropolitan Boston with additional fresh water is the case in point. Resistance from the western part of the State, and particularly for the Connecticut River basin, has forced politicians and planners to examine alternatives more seriously. Wastewater reuse has the opportunity to surface as one of these alternatives. If renovation were to be practiced, more efficient use of existing supplies would allow a delay or elimination of an interbasin transfer of water, and conflict between the eastern and western regions of the state could be abated. Conversely, an inflexible outlook toward conceivable alternatives by the project proponents may persuade other officials that diversion is the only appropriate choice. Reuse of effluent may be unacceptable solely as a result of unfavorable attitudes based on political or other motives.

Another example that may be a result of political reasoning is a delay in construction of a secondary treatment plant. Reuse can remain a paper concept only, if there is no treatment plant or appropriated funds with which to build one. Such a situation exists for one of the participating industries of this study. The engineer acting in an administrative capacity believed reuse of wastewater could be adapted to his plant's needs, but there were no community plans to provide the water. He believed that the delay in compliance with the federal mandate to provide this level of wastewater treatment was politically founded.

Bureaucratic hierarchical structure is another force affecting the feasibility of reuse. In Massachusetts, a reuse plan is most likely to be initiated within the Executive Office of Environmental Affairs (EOEA). Feasibility would be diminished if a plan was not supported here. Consequently, it was important to involve EOEA in this study, and, of the public agencies participating, 75 percent were from this office. One is the Metropolitan District Commission (MDC), an institution well entrenched in the State political structure. Not only is it one of the oldest and largest State agencies, but it wields much power as a result of its sizeable budget. The Commission's acceptance would be crucial to a reuse project if it were to be within the MDC jurisdiction. Presently, MDC attitudes are not favorable, although the individuals interviewed were reluctant to completely dismiss the notion of wastewater reuse. Among the respondents from EOEA, 44 percent did believe reuse could be applicable in Massachusetts.

The communities toward which reuse plans are directed are also apt to be politically involved. Public figures and citizen groups will want to become knowledgeable and kept informed on reuse plans as well as on alternative schemes. If reuse and renovation are to be publicized within the community, an education program must be implemented. Effectiveness can be heightened by involving local public officials and professionals not only in the learning process but in the disbursement of information. Media coverage of their participation will be the key to educating as many people as possible. Newspapers, radio and television can play a very active role by receiving press releases from respected groups such as the Associated Industries of Massachusetts' Industrial Environmental Group. This group could provide an excellent forum to discuss issues of concern from both the community and the industrial perspective, and inform the public of their activities.

As there are many ways to potentially disrupt any water project, reuse proponents should not misjudge the power of special interest groups. These groups will form at the local level, and are best handled by direct communication at the first sign of concern. One industrial respondent suggested the possibility of union resistance in firms utilizing reclaimed water. If special interest unions exist, their participation in the planning process would be warrented.

Participation from larger groups is conventionally achieved by public hearings. At these hearings, those who will ultimately bear the financial burden of a reuse program, via taxation, are given the opportunity to publically voice their opinions and suggestions.

Before public hearings are scheduled it is important for the planners to have a viable set of alternatives from which to work. It is also important that these alternatives be presented to the community upon whom the proposed actions will impact so they may react to each project. These alternatives can be presented both at public hearings and to bond issue voters. Bruvold (1979) described this latter point in his recent discussion on public participation in the adoption of reclamation projects in California. He predicted continued success for reuse projects if voters are given specific options from which to choose as the project is being considered. Interestingly, respondents to Bruvold's surveys "favored most a high degree of wastewater treatment coupled with moderate degree of contact reuse" with minimal treatment and disposal receiving the least support. With this technique, an informed public can participate in technical decisions thereby reducing estrangement from the planning process.

Conservation via reuse. Reuse as a means of water conservation will be a political issue of the future. Reuse is already recognized as having potential for conserving higher quality water by a number of federal and professional agencies and by Massachusetts in its Water Supply Policy Statement (Wallace, et al., 1978). The EPA and the Department of the Interior are channeling funds toward practical application and research on wastewater reuse as a water saving measure.

There is great potential for water conservation efforts in Massachusetts, and a variety of methods are being examined. One effort is by the Massachusetts Division of Water Pollution Control. It granted funds in FY 1979-80 to the Massachusetts Association of Conservation Commissions to encourage communities to submit proposals for projects examining methods of local water conservation. Funding of selected projects will be provided by the Division of Water Pollution Control. Water quality issues will also be included in these studies. Massachusetts could have the ideal opportunity to gain recognition and prominence in the field of water management if greater consideration were given to the reuse potential. The reuse of municipal effluent by industries using large quantities of water is theoretically capable of conserving a portion of fresh water supplies if conditions identified within this current study can be fulfilled.

Hundreds of thousands of gallons of imported water are squandered within the metropolitan Boston area with little regard of its source or value. Six industrial respondents conceded that their water supply was both cheap and plentiful. They claimed that water was not given attention because, in their estimation, it was not warrented until economic pressure caused such attention to be mandatory. Some individuals reported that valves are commonly left open and undetected for days at a time. Public intervention, (indirect political pressure) can help eliminate such useless water waste.

Recyling as a means of water conservation. While almost 54 percent of the firms participating in this survey reported they have a water conservation policy, seven of these have conservation activities limited to the use of cooling towers, where water is recycled to reduce consumption.

The practice of recycling is a primary means of water conservation by industries in general, and may be one worth serious attention even before the examination of the reuse potential. Nationally and internationally, many industries are recycling what was once wastewater, to meet discharge requirements and to reduce raw water intake. Reuse of cooling water as process water, process water reclamation and cooling water recirculation are all viable methods of industrial recycling. Various combinations of physical, chemical and biological treatment processes make it possible to recycle large portions of industrial waste streams, thereby reducing both the volume and strength of the discharge.

Cost savings from recycling can be realized both by the industry and the municipality that provides the treatment facility. The municipality is offered a reduction as a result of the reduced volume of wastewater, in transportation and treatment requirement costs. The industry decreases their raw water charges, and often the cost of the industrial process. Marketable by-products from the pretreatment may be produced and other by-products may be recycled in the manufacturing process itself.

Legal aspects. Institutional feasibility also requires that a myriad of legal and policy questions be acknowledged before the advent of wastewater reuse in the Commonwealth. It is probable that the reason both industrial and public officials had a great concern for risks, many unknown or unpredictable, was the absence of State regulations to govern intentional wastewater reuse.

These aspects are more complex in areas where wastewater is renovated for higher order uses and greater quantities are utilized. California, where reuse is the most prevalent in the nation, has a chapter of the Environmental Health Administrative Code devoted to wastewater reclamation criteria. Known as Title 22, its intent is:

> "to establish acceptable levels of constituents of reclaimed water and to prescribe means for assurance of reliability in the production of reclaimed water in order to ensure that the use... does not impose undue risks to health."
> (State of Calif., 1978)

Water officials in Colorado are relying on reclaimed water to satisfy growing demands. Due to the state's very complex water laws, great efforts have been devoted toward enhancing the legality of wastewater reuse.

In Massachusetts, problems of ownership, liability and risk may arise. Water rights are not directly addressed in the State General Laws Relating to Water and Water Rights (Mass. Water Comm., 1970). Nevertheless, it is advisable that State agencies communicate with each other during the planning of a reuse scheme. The Department of Public Health, the Attorney General's Office and the Executive Office of Commerce and Development will all need briefing by the agency likely to head a plan such as this: the Executive Office of Environmental Affairs. Addressing problems and questions before they become threatening will enhance the renovation and reuse of municipal effluents.

The majority of liability questions will involve the potential for adverse health effects. This problem can be diminished if processes are chosen that do not involve human contact with the renovated water.

Other liability problems, which also encompass risk factors, include possibilities of cross-connections, the subsequent contamination of potable supplies, and circumstances of treatment plant failure. Safeguards against these types of situations must be addressed within the engineering design stage of planning.

The EPA and other governmental and professional agencies are already deeply involved with the planning and technical assistance necessary for new reuse development. Their programs will provide assistance to the State as it considers the reuse feasibility and if a plan is devised.

Support from the EPA begins with their Policy Statement on Water Reuse (U.S. E.P.A., 1978). This short document recognizes the need for reuse, encourages its continued development and practice, and supports the potential for wastewater reuse in many applications including industrial. Here, the agency also announces its continued support for research and development projects.

The Environmental Protection Agency's involvement with reuse is extended as a result of the statutes which they are responsible for enforcing. These include the increasingly stringent federal water quality control laws, specifically P.L. 92-500, (Water Pollution Control Act, 1972). Contrary to what some industrial personnel may believe, this act is not a barrier to reuse of wastewater by industry. Indeed, an incentive is found as both municipal and industrial water users are mandated to comply with increasingly restrictive and expensive wastewater treatment systems.

Although the issue of NPDES permit jeopardy did not surface during the interviews, there has been concern expressed by industries in other states regarding this possibility. A plant using reclaimed wastewater could conceivably exceed the discharge limitation of some constituents regulated by the NPDES program. According to the EPA, Region I, however, discharge restrictions for an industry utilizing renovated wastewater would take into consideration that plant's water source, so as not to discourage reuse.

Engineering Feasibility

It is not within the scope of this report to describe the techniques that have been developed for advanced treatment of wastewater. There is not doubt however, that methods do exist to sufficiently purify water enabling its reuse for a variety of purposes. In Windhoek, Namibia and Pretoria, South Africa, municipal effluent is subjected to advanced treatment enabling the product water to be blended with potable supplies. Denver, Colorado intends to do the same. In Nassau County, New York and in Orange and Los Angeles counties, California, treated effluent is being injected to recharge groundwaters and provide a salt water intrusion barrier. Santee and Lake Tahoe, California have reclaimed water for use in recreational impoundments. Arizona, Washington, California, Austrailia and Israel are some of the many areas using purified wastewater for irrigation purposes. Advanced wastewater treatment has successfully achieved the goal of providing the necessary quality of water for these projects.

The degree of treatment for these human contact uses is generally much greater than that needed for industrial, non-contact purposes. Thus, it can be assumed that an engineering design can be developed to treat municipal effluent so that it will be a reliable product for a particular plant's cooling purposes or process use. With more extensive and expensive purification, effluent can also be suitable as boiler feed or uses that may result in occasional human contact. The exact treatment is a function of the water quality required of the industry.

Water quality requirements. The Massachusetts industries chosen for this study were diversified in type, size and product. Water quality requirements vary among all industries as do the sources of their water supplies. Although water quality at the point of use is critical for many industrial processes, in general, industries' intake water quality requirements are not as stringent as those for potable, recreational or agricultural use. As a result, most manufacturers use surface waters that are not a part of the municipal water supply system. On the other hand, dairy, canning and food processing industries are required to use water that meets drinking water standards. For this reason, examination of the potential for reuse among such industries was eliminated from this study. During the interviews it was discovered that two firms make products subject to Federal Drug Administration approval. At this time, before Massachusetts has experience with industrial use of reclaimed water, or regulations have been established, it would be inadvisable to promote the incorporation of renovated wastewater into such products.

As the results of this research indicated, the interviewed firms' industrial water quality requirements varied from low quality brackish water that is acceptable for once through cooling after minimum treatment, to a highly filtered and deionized water for manufacturing electronic components or feeding steam generators. A wide range of water qualities exist between these two extremes. Further, the interviews with industrial personnel revealed that manufacturers were often unaware of the quality of water they required. They may have known that their existing supply was adequate, but they could not define tolerances or the levels of contaminants that may be present in their current supply. Almost three quarters of the participating industries did not have quality water criteria established for plant uses. It is time consuming and costly to determine tolerance limits, but a firm using water for sensitive processes must identify these limits if and when an alternative water source is sought.

There are a number of published sources that offer water quality characteristics for industrial water supplies. Those relevant to some Massachusetts industries are delineated in the following tables.

TABLE 10: WATER QUALITY REQUIREMENTS FOR COOLING*

Characteristic	Once-through (mg/l)		Makeup for recirculation (mg/l)	
	fresh	brackish	fresh	brackish
Hardness ($CaCO_3$)	850	6250	130	6250
Alkalinity ($CaCO_3$)	500	115	20	115
Calcium (Ca)	200	420	50	420
Sulfate (SO_4)	680	2700	200	2700
Chloride (Cl)	600	19000	500	19000
Silica (SiO_2)	50	25	50	25
COD (O_2)	75	75	75	75
Dissolved solids	1000	35000	500	35000
Suspended solids	500	2500	100	100

*Water Quality Criteria, FWPCA, Washington, D.C. (April, 1968)

TABLE 11: WATER QUALITY REQUIREMENTS OF INDUSTRIAL BOILER FEEDWATER*

Characteristic	Minimum Requirements (mg/l)		
	0-150 psig	150-700 psig	700-1500 psig
Hardness ($CaCO_3$)	20	0	0
Alkalinity ($CaCO_3$)	140	100	40
Silica (SiO_2)	30	10	0.7
Aluminum (Al)	5	0.1	0.01
Iron (Fe)	1	0.3	0.05
COD (O_2)	5	5	0.5
Dissolved solids	700	500	200
Suspended solids	10	5	0

*Water Quality Criteria, FWPCA, Washington, D.C. (April, 1968)

As Table 10 indicates, criteria widely differ according to types of cooling water and the sources. For instance, recirculated cooling water must be lower in calcium carbonate because it increases in concentration (due to evaporation) with sequential use. In fact, lower levels are required for most characteristics when the cooling water is to be recirculated. The minimum requirements for boiler feed purposes (Table 11) vary according to boiler pressure. Criteria such as these are a preliminary indication of the water quality that some industries will need for their cooling purposes and for boiler feed.

Dual systems. There is no intention to suggest that reclaimed water be used for drinking purposes and food preparation within industrial plants. Because a potable water system is always warrented, dual water supply lines are inherently necessary. Such systems are not new to large industries. Often a number of different water supply streams are utilized within a plant; raw water for cooling, a higher quality for process use, a demineralized water for boiler feed and a bacteriologically safe water for drinking.

Respondents indicated their reluctance to believe the costs of a dual system would still result in a cost-effective wastewater reuse project. As outlined in the discussion on economics, however, this expenditure would be weighed with other costs and benefits to determing the merits of the alternative reclaimed water sources.

It is probable that the age, layout or size of some plants is a bona fide deterrant to the construction of a new water line. New or small plants, as well as those with separate buildings for different purposes could be candidates for dual system installation, however.

It is conceivable that backflows will occur between a non-potable water source and the drinking water lines when a dual water system exists. The possibilities are very slight, however, in cases where the two lines are physically distant, such as with a cooling tower and a potable system. Within large industrial plants there is no reason to believe that overly hazardous situations would exist if reasonable precautions were observed.

CHAPTER VI

CONCLUSIONS

Despite the need for more consideration of wastewater reuse in Massachusetts, the results of this study indicate that water resource officials are not inclined to accept reuse as a viable means of water conservation. Their reasons are primarily based on economics and the potential for other water supply sources. Therefore, the political feasibility is considered to be poor. Agency officials did express retrospective concern for better planning. It was as if they lamented inactions of the past and now realized the time for positive decision-making was overdue. This hesitancy may be an indication of how these officials react to new concepts that may help solve old problems. Increased severity of water supply problems could cause their attitudes to change.

The social feasibility is more promising. Surprisingly, the results indicate that industries using large amounts of water are more receptive than the public sector to the prospect of a renovated wastewater use project. Industry's favorable attitude is deceiving, however, without considering their insistance on such a project's economic viability. In other words, they do not see a need for reusing wastewater at this time, and because of this, they have attached stipulations relating to cost-effectiveness prior to their general acceptance.

The economic feasibility cannot be known, however, until plans for a specific project are developed. At that time it would be appropriate for water resource plans to be examined holistically. The systems approach can be used for this type of water delivery planning. This method, which considers reuse and other options, would be used to analyze the interrelationships among water quality control and water supply programs, and pertinent physical, economic and administrative factors. By examining all possible input factors, based on the results of the feasibility tests suggested within this report, a model may be developed that is sensitive to temporal and technical changes.

Economic analysis of a reclaimed wastewater system will enhance acceptance, provided the analysis indicates cost-effectiveness. However, systems analysts recognize that economics are apt to fluctuate over time, perhaps altering their evaluation. Reconsideration of the analysis as events change is warrented. The key here is comprehensive and reliable economic evaluations. Many factors are easily overlooked, which may be very pertinent in the analysis. These elusive factors are currently being studied by other investigators. To date there are no conclusions and economic analyses of wastewater renovation projects are still in the infant stages.

Where water is abundant it is normal for industries to resist efforts to institute effluent reuse programs. Incentives must be offered. These incentives should not only be of an economic nature, but in the form of factual information and data from a reliable cost/benefit analysis. If the cost/benefit ratio is greater than one the initiation of a pilot project demonstrating reliability and cost-effectiveness is advisable. Economic and technical aspects could be presented and hopefully reassure the industrial sector and the general public. Proof that reuse can be practiced in the Commonwealth would enhance its image and respectability.

Unfortunately, the critical potable water shortage is unrecognized by many in the industrial sector. Although water rates are increasing, they are a small portion of an industry's capital expenditures and have not received proper attention. It is apparent that comprehensive programs should be instituted so that more attention is given to the recent State Water Supply Policy Statement. Further, once firms recognize that water is a valuable and limited resource, reuse may become more readily acceptable.

The limited knowledge regarding wastewater reuse by some respondents in both of the groups surveyed is alarming. Evidence presented indicated that faith in reclamation technology is absent and the opportunity wastewater reuse offers to conserve potable water is unrecognized even though the engineering feasibility exists for most plants.

The data suggest that there is confusion regarding wastewater renovation among industrial personnel. While a majority would not accept reclaimed water of the same quality as drinking water if it were to cost the same as their current supply, only one more respondent rejected rather than accepted reclaimed water of a lower grade than their current supply if the cost was the same. One would expect that more respondents would object to equal costs under the latter condition than the former. A clear understanding of the reuse concept is obviously lacking. Misconceptions regarding wastewater reuse must be corrected before it will be generally accepted. Again, an education program must be developed if reuse is to become a reality.

It is true that New England is plentifully endowed with fresh surface water. It is also true that insufficient amounts of this water are developed to serve current and future demands, and approximately two decades are needed to activate new water resource development plans. Public officials, particularly engineers, indicated their reluctance to investigate the possibilities that wastewater reuse may have to augment current supplies and to provide a "time cushion" allowing the development of new sources. An optimal combination of waste and water supply treatment is required to maintain the desired water quality standards for water in use and water in transit at the least cost.

In order to boost Massachusetts' economic development, the State should consider attracting industries that may have difficulties in areas with water shortages. While New England is richly endowed with running streams, planners should be careful not to rely on resources that are as yet undeveloped. Reuse can offer a reasonable and environmentally sound alternative. This study indicates that it is industry which is closer to providing the impetus for this alternative while public officials who have a duty to explore long term solutions are still relying on traditional, multi-million dollar projects to obtain water far from the scene of its use...and waste.

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APPENDIX A

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AMHERST, MASSACHUSETTS 01002

Dear

The University of Massachusetts Water Resources Research Center is conducting a survey of industry's attitudes toward the potential use of reclaimed municipal wastewater. Because your plant uses a relatively large quantity of water the Center wishes to obtain your view on such reuse.

On several occasions the State Executive Office of Environmental Affairs has stated that reuse of municipal sewage effluent could be an important component of a comprehensive water conservation program.

The information the Center would find helpful is reflected in the following questions:

1. How much water does your industry use on an average daily basis?
2. What are the specific water quality requirements associated with each plant use?
   a) have water quality criteria been established for the various plant uses? (Criteria of interest include microbiological contaminents, total dissolved solids, turbidity, hardness, heavy metals, temperature and other impurities.)
   b) would your industry be willing to accept reclaimed sewage effluent if it met your quality requirements?
3. What economic incentives to industry do you believe are desirable and feasible to encourage reclamation by industry?
4. Do you believe the use of reclaimed municipal wastewater by industry is a promising method of conserving water?

5. Has your industry (which includes your plant) adopted any policy on water conservation?
6. What is the feasibility of providing a dual water system within your plant to accomodate use of both public water supply and reclaimed municipal sewage effluent?

We propose to obtain this information, so far as it is available, by interviewing yourself or a designated representative. We hope that you will agree to help us. I will call you soon to make an appointment for the interview.

Respectfully,

Janice Pratte
Graduate Research Assistant

APPENDIX B

QUESTIONS FOR INDUSTRIAL OFFICIALS

CITY ______________________ TIE-IN ____________ DISCHARGE ________

1. How much water does your industry use on an average daily basis? (GPD)

   __50,000 __50,000-100,000 __100,000-125,000 __125,000-150,000

   __150,000-175,000 __175,000-200,000 __200,000 or more ___MGD

   a) Are there significant variations in average daily water usage monthly or seasonally?

      ___no ___yes, monthly ___yes, seasonally

      ___yes, unpredictable

         ___significant variation

         ___moderate variation

         ___insignificant variation

   b) What is water used for and what estimated quantities are required for each specific use?

      USE QUANTITY

      ___cooling

      ___boiler feed ___domestic

      ___blowdown ___other

      ___process

2. What are the specific water quality requirements associated with each plant use?

   USE REQUIREMENT

   ___cooling

   ___boiler feed

   ___blowdown

   ___process

   ___other

Have water quality criteria been established for the various plant uses?

___microbiological contaminents ___yes ___no ___criteria not set

___TDS ___yes ___no ___criteria not set

___turbidity ___yes ___no ___criteria not set

___hardness ___yes ___no ___criteria not set

___heavy metals (name) ___yes ___no ___criteria not set

___temperature ___yes ___no ___criteria not set

___other impurities (name) ___yes ___no ___criteria not set

2b) Would your industry be willing to accept reclaimed sewage effluent if it met your quality requirements?

___yes ___no ___maybe

i) Would you be willing to pay the same price for reclaimed wastewater as for public water supply assuming the reclaimed water meets national drinking water standards?

___willing ___willing but unable ___not willing

ii) Would you be willing to accept and upgrade reclaimed wastewater of lower than drinking water quality assuming the cost of the water, including the cost to upgrade the water, does not exceed present costs?

___willing ___willing but unable ___not willing

iii) Would you be willing to accept and upgrade reclaimed wastewater of lower than drinking water quality assuming the sum of the costs of of the reclaimed water and its upgrading, and of the user charge for sewerage service, do not exceed the present cost for water and sewerage service?

___willing ___willing but unable ___not willing

___the sum would definitely exceed the present cost

3. What economic incentives to industry do you believe are desirable and feasible to encourage reclamation by industry?

3a) What is the basis of your water rates?

___flat ___metered ___other

4. Do you believe the use of reclaimed municipal wastewater by industry is a promising method of conserving water?

___yes, we use a lot of water that could be of a lower grade.

___yes, we waste a lot of high quality water.

___yes, we must find a way to cut increasing water costs.

___yes, it's the easiest way to conserve water under our circumstances.

___yes, it would insure a constant supply.

___yes, other ______________________________

___no, ______________________________

5. Has your industry (which includes your plant) adopted any policy on water conservation?

___yes ___no ___the industry has or is considering it

5a) Does your plant recycle water?

___yes ___no ___under consideration

6. What is the feasibility of providing a dual water distribution system within the plant to accomodate use of both public water supply and reclaimed municipal sewage treatment plant effluent?

___	___	___	___	___	___
not feasi- ble	feas. w/grt. difficulty	feas. w/moderate difficulty	feas. w/little difficulty	somewhat feasible	very feasible

Reasons: ______________________________

____

Comments: ______________________________

____

APPENDIX C

UNIVERSITY OF MASSACHUSETTS
AMHERST · BOSTON · WORCESTER

WATER RESOURCES RESEARCH CENTER
OFFICE OF THE DIRECTOR
GRADUATE RESEARCH CENTER
AMHERST, MASSACHUSETTS 01002

Dear

The University of Massachusetts Water Resources Research Center is conducting a survey of industry's and public officials' attitudes toward the potential use of reclaimed water by industry in Massachusetts. Because you would undoubtably be involved in the decisionmaking process the Center wishes to obtain your view on such reuse.

This project was prompted in part by the position of the State Executive Office of Environmental Affairs which has stated that reuse of municipal sewage effluent could be an important component of a comprehensive water conservation program.

The Center would be particularly interested in your views on the following:

1. Your attitudes toward the use of municipal sewage effluent by industrial plants.

2. Problems you would anticipate in providing reclaimed municipal sewage effluent to industries.

3. Public policy with regard to granting economic incentives to industry to encourage use of reclaimed municipal sewage effluent.

4. The use of reclaimed water by industry as a promising method of conserving water in Massachusetts.

We should like to obtain this information, and more, by a personal interview with you. We hope that you will agree to help us. I will call you soon to make an appointment for a meeting.

Respectfully,

Janice Pratte
Graduate Research Assistant

APPENDIX D

1. What are your major concerns for the future of water supply and/or treatment in Massachusetts?

2. How would you describe your attitude toward the use of reclaimed municipal sewage effluent by industrial plants?

3. Are you familiar with wastewater reclamation projects for use by industry in other cities? If so, what is your attitude toward these programs?

4. What problems would you anticipate in providing reclaimed municipal sewage plant effluent to industries?

5. Do you believe that health concerns may be an issue with regard to industrial use of municipal sewage effluents?

6. What should public policy be with regard to granting economic incentives to industry to encourage use of reclaimed sewage effluent?

   a) What economic incentives, if any, may be appropriate with respect to the cost of construction and operation of a reclaimed wastewater distribution system?

   b) Should the public agency or the industrial plant be responsible for upgrading the quality of municipal sewage effluents (beyond that of secondary treatment) to meet the plant's water quality requirements?

   c) Do you think that supplying industries with MDC effluent is economically feasible?

7. What specific recommendations would you make with regard to future policy of providing reclaimed municipal sewage effluent to industrial plants within your area of jurisdiction?

8. Do you believe the use of reclaimed water by industry to be a promising method of conserving water for Massachusetts? What other methods may be as good or more preferable and why?